Knowledge Management Research & Practice (2015) 13, 418–428

www.palgrave-journals.com/kmrp/

Open

Gestalt principles of creating learning business ontologies for knowledge codification

Tatiana Gavrilova[1]
Irina Leshcheva[1] and
Elvira Strakhovich[1]

[1] *Graduate School of Management, St. Petersburg State University, St. Petersburg, Russia*

Correspondence: Elvira Strakhovich, Graduate School of Management, St. Petersburg State University, Volkhovsky per., 1-3, St. Petersburg 199004, Russia.
Tel: +7(921)9137718;
E-mails: gavrilova@gsom.pu.ru; leshcheva@gsom.pu.ru; strakhovich@gsom.pu.ru

Abstract
This paper presents an approach aimed at creating business ontologies for knowledge codification in company. It is based on the principles of ontological engineering and cognitive psychology. Ontologies that describe the main concepts of knowledge are used both for knowledge creation and codification. The proposed framework is targeted at the development of methodologies that can scaffold the process of knowledge structuring and orchestrating for better understanding and knowledge sharing. The orchestrating procedure is the kernel of ontology development. The main stress is put on using visual techniques of mind mapping. Cognitive bias and some results of Gestalt psychology are highlighted as a general guideline. The ideas of balance, clarity, and beauty are applied to the ontology orchestrating procedures. The examples are taken mainly from the project management practice. The paper contributes to managerial practice by describing the practical recommendations for effective knowledge management based on ontology engineering and knowledge structuring techniques.
Knowledge Management Research & Practice (2015) **13**(4), 418–428.
doi:10.1057/kmrp.2013.60; published online 20 January 2014

Keywords: knowledge management; business ontologies; cognitive visual design

Introduction

Top managers and IT analysts are continually challenged by the need to analyse massive volumes and varieties of multilingual and multimedia data for decision making. There is special interest in knowledge work in the modern organizations (Cunha & Putnik, 2006; Leydesdorff, 2006).

Knowledge management (KM) is one of the powerful approaches to solve these problems (Firestone & McElroy, 2005). KM is aimed at solving the problems of information overload, 'brain drain', misunderstanding, low efficiency and information-based difficulties. But for top managers and business analysts it is still a rather new, eclectic domain that draws upon areas like system thinking, cognitive science, management and communication psychology. Accordingly, KM has been, and still is, in danger from fragmentation, incoherence and superficiality. The paper presents a new approach to practical codification of knowledge conceptual structures (or ontologies) to support KM processes. This approach can help practitioners in the visual design of ontologies.

Central problems for supporting all phases of knowledge processing are the productivity of the knowledge workers and the effective usage of special professional techniques. Company staff and employees as knowledge workers require support and guidelines for knowledge sharing and codification processes within the KM framework (Eppler & Platts, 2009).

Received: 10 December 2012
Revised: 24 September 2013
Accepted: 06 December 2013

During the last decade, visual knowledge mapping has become one of the key considerations in KM and enterprise modelling methodology and it is heavily associated with ontology design and development (O'Donnell *et al*, 2002; Vestal, 2005). Alongside this, so-called learning business ontologies have arguably come to play a central role in knowledge transfer and sharing. These ontologies, which are built on conceptual skeleton of the organizational domain knowledge, might serve various purposes such as better understanding, knowledge sharing, and collaborative learning, problem solving, seeking advice, or developing competences by learning from peers.

Recently, ontological engineering perspective has gained interest in the domain of organizational learning (especially blended learning) and cognitive psychology involving the study of the structure and patterns of knowledge. These studies rely heavily on theory and tools from knowledge engineering analysis that has already a long-standing tradition in the knowledge-based systems domain (Mizoguchi & Bordeau, 2007). The tools and techniques developed in this domain can be applied fruitfully in the field of company knowledge structuring and design (Schreiber, 2000; Knight *et al*, 2006).

Ontological engineering can also be used as an effective research instrument to study how the structure and patterns of the domain knowledge are related to business processes and information management. Much of the research so far has focused on a limited number of formal representations that are typically easy to be developed while cognitive and methodological issues are rather underestimated. Furthermore, categorization and laddering as the creative synthesizing activities also did not receive much attention in modern knowledge studies while they proofed their importance in socio-technical and management research.

Regardless of how ontological engineering is used, in all cases it is necessary to analyse the design procedure. The described ontologies were designed and orchestrated for the courses on KM delivered by the author in face-to-face and e-learning formats for MBA and EMBA programmes in Graduate School of Management at Saint-Petersburg State University, HEC (Paris) and Aalto University (Helsinki).

The aim of this study is to develop the methodology and some practical recommendations how to train practitioners for design of visual ontologies that can be used for knowledge codification, transfer, sharing and dissemination in companies. These ontologies may support business decision making efficiently also.

We start with reference to the structuring methods that can help the knowledge work. Ontology is in focus as a tool for the systemic hierarchical conceptual specification of any complex object or business domain. We provide our vision of the mainstream state-of-the-art categorization in ontological engineering that may help the knowledge analyst to figure out what type of ontology he/she really needs. We put stress on visual design and use of mind mapping and concept mapping as they proved to be powerful visual tools. Next, we simplify different approaches, terms and notations for practical use and propose a four-step recipe for practical visual ontology design. Then we provide our case to illustrate the using of the described recipe to practical business ontology design. We conclude with some implication for ontology usage for effective KM practice and decision making.

This paper traces the cognitive foundations of business ontology design and development using the methods of structured ontological engineering. The paper attempts to propose the new methodology and practical tips how to help the knowledge workers to develop business ontologies. The methodology combines system approach with cognitive ergonomics principals. The purpose of the described methodology is to provide business analysts in companies with the distinct recommendations in ontology design and orchestrating for better knowledge transfer and sharing. The skilful knowledge workers can truly increase the productivity and sustainability of modern business practice in the innovative service-oriented economy by using proposed approach.

Business ontologies

The numerous well-known definitions of 'ontology' – this milestone term – (Neches *et al*, 1991; Gruber, 1993; Guarino & Giaretta, 1995; Uschold, 1998; Mizogushi & Bourdeau, 2000) may be generalized as 'Ontology is a hierarchically structured set of terms for describing an arbitrary domain' (Gómez-Pérez *et al*, 2004).

Ontologies can be used to describe any particular business world. But our experience in training shows that no one can deal with ontologies without knowledge engineering practice.

The lack of structured guidelines and methods hinders the development of shared and consensual ontologies within and between the teams. Moreover, it makes the extension of a given ontology by others, its reuse in other ontologies, and final applications difficult (Guarino & Giaretta, 1995).

The idea of using visual structuring of ontologies or any other information model to improve the quality of knowledge transfer, general awareness and understanding is not new. For more than 20 years mind mapping (Busan, 2005) and concept mapping (Sowa, 1984; Jonassen, 1998; Conlon, 2006) has been used for providing structures and mental models that support the process of organizational learning.

As such, the visual representation of general domain concepts facilitates and supports employees' understanding of both substantive and syntactic knowledge. Many managers, especially those who work with novices, operate as a knowledge analysts or knowledge engineers by making visible the skeleton of the company knowledge and showing the domain's conceptual structure (Kinchin *et al*, 2005). Also this structure may be later represented as 'ontology'.

However, ontology-based approach to knowledge representation in companies is a relatively new development. Ontology is a set of distinctions we make in understanding

and viewing the world. There are numerous definitions of this milestone term (Neches *et al*, 1991; Gruber, 1993; Guarino & Giaretta, 1995; Gómez-Pérez *et al*, 2004). Together, these definitions clarify the ontological approach to knowledge structuring while giving enough freedom to open-ended, creative thinking. So, for example, ontological engineering can provide a clear presentation of company main concepts (services, processes, projects, etc.) and their inter-relationships.

Many researchers and practitioners argue about distinctions between ontology and a conceptual model. We suppose that ontology corresponds to the analyst's view of the conceptual model, but is not *de facto* the model itself. There are more than one hundred of the techniques and notations that help to define and to visualize the conceptual models. Ontologies now supposed to be the most universal and sharable forms of such modelling.

It originated in knowledge engineering (Boose, 1990; Wielinga *et al*, 1992; Tu *et al*, 1995), and then it was transferred to KM (Fensel, 2001). Ontologies are useful structuring tools, in that they provide an organizing axis along which every specialist can mentally mark his vision in the information hyper-space of domain knowledge. Frequently, it is impossible to express the information as a single ontology. Accordingly, company knowledge storage provides for a set of related ontologies. Some problems may occur when moving from one ontological space to another, but constructing meta-ontologies may help to resolve these problems.

Meta-ontology provides more general description dealing with higher level abstractions. Figure 1 illustrates different ontology classifications in the form of the mind map. Mind mapping (Buzan, 2005) and concept mapping (Novak & Cañas, 2006) are now widely used for visualizing of the ontologies at the design stage.

A mind map is a diagram used to represent words, ideas, tasks, or other items linked to and arranged around a central key word or idea. The central topic sits in the middle with related topics branching out from it. Ideas are further broken down and extended until knowledge analyst has fully explored each branch of the map. Mind maps are used to generate, visualize, structure, and classify ideas, and as an aid in study, organization, and writing. British popular psychology author Tony Buzan claims to have invented modern mind mapping. Buzan argues that while 'traditional' outlines force readers to scan left to right and top to bottom, readers actually tend to scan the entire page in a non-linear fashion.

A concept map is a diagram showing the relationships among concepts. Such maps are graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts. One way to use concept maps for KM is to have specialists create maps about their professional activity. This allows managers to determine the level of knowledge of shared knowledge.

The concept maps represent and clearly name both objects and relations between objects, while mind maps only present objects and the hierarchy of them. The mind map and concept map modelling can be applied to developing those KM systems where general understanding is more important than factual details.

Ontology visual design also may be used as a procedure with big expressive power to externalize the company knowledge. Such expressive tools give the professionals the opportunity to express their own models about reality and so give others the chance to learn through these representing, exploring and reflecting on the consequences of ontologies.

Knowledge entities that represent static knowledge of the domain are stored in the hierarchical order in the knowledge repository and can be reused by others. At the same time those knowledge entities can be also reused in description of the properties or methodological approach as applied in the context of another related knowledge entity.

By static knowledge we mean that the main knowledge patterns don't change at some given period of time. They are supposed to be the same during the substantial period.

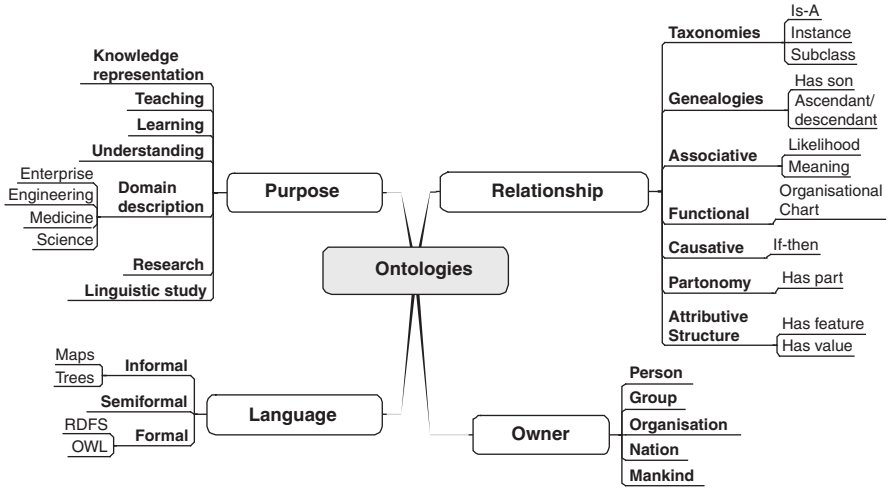

Figure 1 Summarizing the ontology classifications in a mind map.

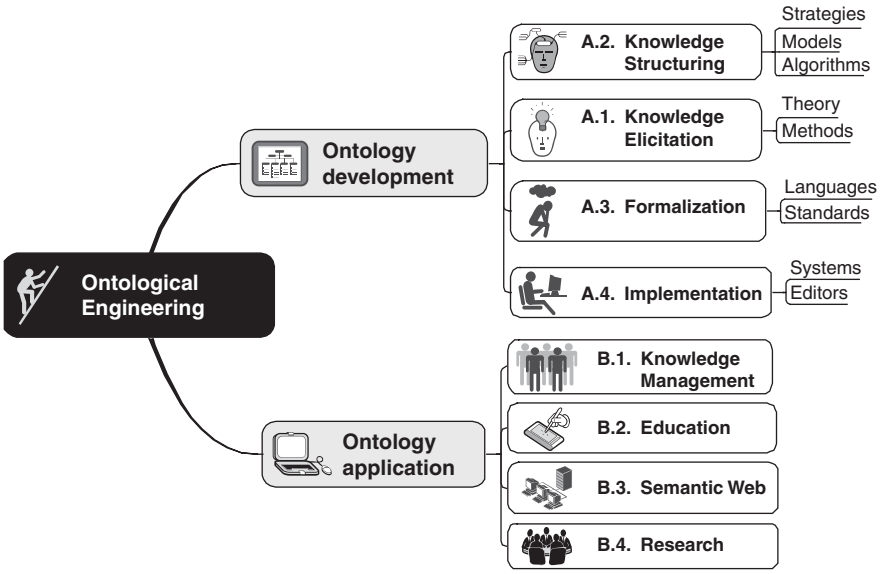

Figure 2 Ontological engineering.

Ontological engineering

We propose a new scheme for describing the ontological engineering as presented in Figure 2. It covers all the issues of ontology development and applications. But it is an unfortunate tradition that technological aspects are much more explored than the methodological ones. Ontology development still faces the knowledge acquisition bottleneck problem, as it was described in the work of Guarino & Giaretta (1995). Even the last decade when some effective tutorials on ontology development were presented (Mizoguchi & Bourdeau, 2000; Noy & McGuinness, 2001), the absence of structured guidelines and methods hindered the development of shared and consensual ontologies within and between teams; the extension of a given ontology by others; and its reuse in other ontologies and final applications.

Until now, few domain-independent methodological approaches have been reported for building ontologies (Blazquez *et al*, 1998; Fensel, 2001; Noy & McGuinness, 2001; Dicheva & Aroyo, 2004). These methodologies have in common that they start from the identification of the purpose of the ontology and the need for domain knowledge acquisition. However, having acquired a significant amount of knowledge, major researchers propose a formal language expressing the idea as a set of intermediate representations and then generating the ontology using translators. These representations bridge the gap between how people see a domain and the languages in which ontologies are formalized.

The business analyst as the ontology developer comes up against the additional problem of not having any sufficiently tested and generalized methodologies recommending what activities to perform and at what stage of the ontology development process these activities should be performed. That is, each ontologist usually follows his/her own set of principles, design criteria, and steps in the ontology development process.

This paper proposes a clear, explicit approach to ontology design – to use the visual, iconic representation in a form of a tree or set of tree diagrams/structures. The figures will illustrate the idea how ontology can bridge the gap between the chaos of unstructured knowledge and a clearly mapped representation. However, ontology developers who are unfamiliar with or simply inexperienced in the languages in which ontologies are coded, (e.g. DAML, OIL, RDF) may find it difficult to understand how such ontologies have been created, and, conversely, even how to build a new ontology.

At the basic level of knowledge representation, within the context of everyday heuristics, it is easier for analysts to simply draw the ontology using conventional 'pen and pencil' techniques. It is useful and illuminating to allow specialists to create multiple representations (perhaps using different tools) of the same content.

Simple recipe for ontology design

The existing methodologies describing ontology life cycle (Uschold & Gruninger, 1996; Mizogushi & Bourdeau, 2000; Sebastian *et al*, 2008; Blanchard *et al*, 2009) deal with general phases and sometimes don't discover the design process in details. Although in major works the emphasis is put on ontology specification (or coding), we would like to elucidate again the essentials of ontology capture in the simplest form as a recipe for 'dummies' (Gavrilova *et al*, 2006):

Step A. Goals, strategy, and boundary identification.

Step B. Glossary development and meta-concept identification.

Step C. Laddering, including categorization and specification.

Step D. Orchestrating or refinement.

A. Goals, strategy, and boundary identification

The first step in ontology development should be to identify the purpose of the ontology and the needs for the domain knowledge acquisition. It is important to be clear about what type of the ontology (see Figure 1) is being built (taxonomy, partonomy, genealogy, etc.) and what level of granularity the concepts is. We also need to elucidate the scope or 'boundaries' of the ontology, before compiling a glossary. That effort is done at this step, as it affects the following stages of the design.

B. Glossary development and meta-concept identification

This time-consuming step is devoted to gathering all the information relevant to the professional domain. The main goal of this step is selecting and verbalizing all of the essential objects and concepts in the domain. A battery of knowledge elicitation techniques may be used – from interviews to free association word lists.

C. Laddering, including categorization and specification

Having all the essential objects and concepts of the domain in hand, the next step is to define the main levels of abstraction. Consequently, the high-level hierarchies among the concepts should be revealed and the hierarchy should be represented visually on the defined levels. This could be done via a top-down strategy by trying to break the high-level concept from the root of the previously built hierarchy, by detailing and specifying instance of concepts. Revealing a structured hierarchy is one of the main goals at this stage. Another way is generalization via bottom-up structuring strategy. Associating similar concepts to create meta-concepts from leaves of the aforementioned hierarchy could do this.

The main difficulty is forming categories by creating high-level concepts and/or breaking them into a set of detailed ones where it is needed. Categorization is one of the higher cognitive activities, and it is a teacher's work to create and label all the main categories, sub-categories, and concepts of the teaching content. The other employees may be involved in this process also. The collaborative work in groups sometimes gives positive synergetic effect if it puts stress on structuring methodology.

D. Orchestration

This term means the harmonious organization (Merriam-Webster Online Dictionary, 2008). The final step is devoted to updating the visual ontology structure by excluding any excessiveness, synonymy, and contradictions. The main goal of this final step is to create a beautiful or harmonious ontology.

Beauty is a characteristic of an object, or idea that provides a perceptual experience of pleasure, meaning, or satisfaction. Beauty is studied as part of aesthetics, sociology, social psychology, and culture. Of course there are cultural differences in perception of beauty. The experience of 'beauty' often involves the interpretation of some entity as being in balance and harmony with nature, which may lead to feelings of attraction and emotional well-being. Because this is a subjective experience, it is often said that 'beauty is in the eye of the beholder' (Martin, 2007). But in many cases people agree at the evidently beautiful structures.

The ideas of 'beautification' are well known in basic studies beginning from the search for beautiful formula, model, or result. Beauty was always a very strong criterion of scientific truth. We believe that harmony and clarity are the main properties that make an ontology beautiful.

Visual ontology orchestrating

Bearing in mind that corporate ontologies are to be used not only as a knowledge component of the KM system but also as a mind tool for comprehensiveness and better understanding, we tried to follow the principle of good shape (or beauty) that is not new in basic scientific abstraction and modelling (e.g. physics, chemistry, etc.). It is difficult to give the formal definition of this concept but it features the imprecise sense of harmonious or aesthetically pleasing proportionality and balance. The most substantial impulse to it was given by the German psychologist Max Wertheimer. His criteria of good Gestalt (image or pattern) (Wertheimer, 1945) we partially transferred to ontological engineering:

- Law of Pragnanz (the law of good shape) – *the organization of any structure in the nature or cognition will be as good as the prevailing conditions allow. 'Good' here means regular, complete, balanced, and/or symmetrical.*
- Law of Parsimony – *the simplest example is the best (the Ockham's razor principle): entities should not be multiplied unnecessarily.*
- In the case of building ontological hierarchies, we have to keep in mind that a well balanced hierarchy corresponds to a strong and comprehensible representation of the domain knowledge. We enlist below some tips that we consider useful in formulating the idea of 'harmony' (Gavrilova, 2010):
- Concepts of one level should be linked to their parent concept by one type of relationships, for example, 'is-a', 'has part', etc. This means that concepts of one layer have similar nature and level of granularity.
- The ontology tree should be balanced, that is, the depth of the paths in the ontological tree should be more or less equal (±2 nodes). This will also insure that the general layout is symmetrical. Asymmetry means that shorter branch is less investigated or longer one is too detailed (see Figure 3).
- Cross-links should be avoided as much as possible.

Moreover, when building an ontology, which is used for information visualization and browsing, it is important to pay attention to clarity. Minimizing the number of concepts is the best tip according to the Law of Parsimony. The maximal number of branches and the number of levels may follow Miller's 'magical number' (7±2), which is related to the human capacity for processing information (Miller, 1956).

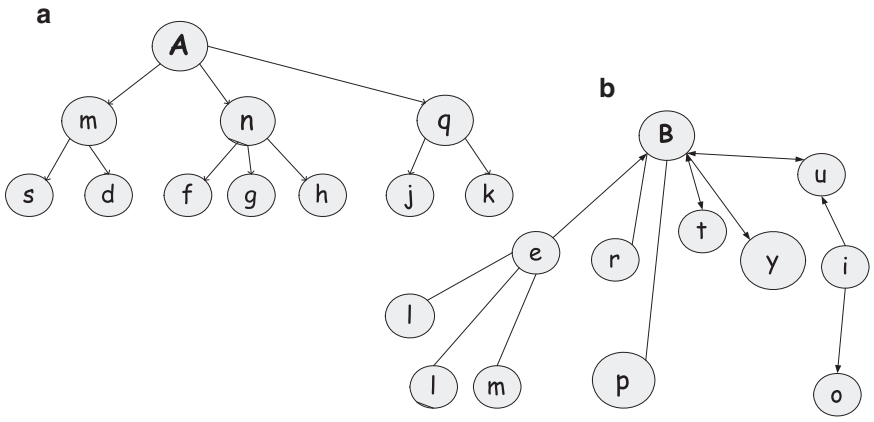

Figure 3 Well-balanced (a) and ill-balanced (b) ontologies.

'Beautification' bias works as a strong methodological approach that helps find the points (nodes) of 'growth', 'weak' branches, inconsistence, and excessiveness. But, in fact, specific domain knowledge features may be of higher priority than design principles.

We have produced several simple hints to refine and illuminate the ontology's design stage.

1. Use different font sizes for different levels.
2. Use different colours to distinguish particular subsets or branches.
3. Use a vertical layout of the tree structure/diagram.
4. If needed, use different shapes for different types of nodes.

We have already developed more than 20 business ontologies (Gavrilova & Laird, 2005).

Also several research ontologies were developed to help the research community to generalize their shared understanding – the domains were 'user modelling' (with Peter Brusilovsky and Michael Yudelson) (Brusilovsky *et al*, 2005), ontologies in education (with Darina Dicheva and Sergey Sosnovsky) (Gavrilova *et al*, 2005a, b) and medicine (Gavrilova & Bolotnikova, 2012).

As we are speaking about the pre-design stage of creating light-weight ontologies (without formalizing into OWL or other language), the usage of any available graphical editors may be helpful. These editors work as powerful assistants. The best results we received were when using mind mapping and concept mapping tools.

But any effective computer program for ontological engineering should perform the functions described for structuring the stages of a subject domain. Accordingly, it should correspond to the phenomenological nature of the knowledge elicitation involved using different appropriate algorithms. This program must support the knowledge engineer through incorporating 'game rules' that are clearing, transparent, and functional. Ideally, the knowledge engineer should be able to tailor the program to his or her specific requirements. Concerning this, each analytical stage may be represented visually and accurately modelling the knowledge domain, an element that has already been realized in some commercial expert system shells.

To achieve these goals, a set of special visual tool were developed and named CAKE-2, VICONT, PORTO, and VITA (together with Tim Geleverya, Alex Voinov, Vitaliy Fertman, and Vladimir Gorovoy). They illustrate the idea of knowledge mappability as applied to data extraction, analysis, and structuring for heterogeneous knowledge base design (Gavrilova & Voinov, 1998; Gavrilova *et al*, 2004–2006, 2010, 2012).

Developing practical business ontologies

We can propose different types of business ontologies that can substantially aid effective knowledge sharing:

- Main concepts ontology (or conceptual structure).
- Historical ontology (genealogy).
- Partonomy of the complex processes and products, where the main relation between learning objects is 'has_part'.
- Taxonomy of the customers, services, methods and techniques, etc.

Ontology-based approach is universal. In this section, we describe our attempt to develop the ontology from the scratch. We have tried to report the exact practical procedures we followed at each step by including all the visual structures.

The example below illustrates the ontology that describes the skeleton of the project as the main concept of the project management domain. It integrates the main theoretical and practical issues of this multi-disciplinary and multi-faceted area. Project-based approach is now very popular in many sectors of business.

Steps A and B: goals identification and glossary development

As previously mentioned the first steps in building ontology consist of strategic planning and collecting information in the domain. Then the glossary building of terms for the domain is conducted. To build a glossary for project management, we have collected the terms from Project

Table 1 Glossary of the terms for project management.

acceptance criteria	negotiation	historical estimating
activity definition	concept phase	human resource management
activity duration	contract	impact
activity sequencing	crashing	incremental approach
stat date	criteria	initiating processes
finish date	critical path	priority
agreement	project life cycle	kickoff meeting
baseline	decision making	lessons learned
alternatives analysis	decision tree	assurance
prototyping	defect	metrics
cost	dependency	milestone
effort	design	schedule
assumption	review	risk
audit	development	monitoring
authority	methodology	objective
bottom-up estimating	deviation	quality
brainstorming	documentation	organization chart
work breakdown structure	duration	outsourcing
budget	effort	planning processes
business case	environment	project plan
process model	executing	resource
capability maturity model	feedback	sponsor
calendar	failure	stakeholder
change control board	fast-tracking	proof of concept
change management	error	release
change control procedure	defect	traceability
change management plan	feasibility	responsibility
change request	fishbone diagram	testing
project charter	fixed cost	training
checklist	functional manager	validation
closing processes	functional requirement	verification
commitment	Gant chart	version
communication management plan	goal	virtual team
skills	project team	warranty

Management Body of Knowledge (PMBOK Guide, 2008), our experience and tutorials. All terms were extracted manually. Table 1 presents the combined unsorted glossary.

Some preliminary hierarchies may be revealed on the basis of the glossary. The mind map can be useful for visual structuring of these hierarchies and will be created at the next step.

Step C: laddering

This step contains the sequence of the stages to create an ontology for the 'project' concept. The main goal of the first stage is to create the sets of preliminary ideas and notions and to categorize those terms into concepts. Figure 4 presents the mind map of that initial categorization. Since the categorization in this stage was preliminary, some of terms might not fit into any of the initial categorization.

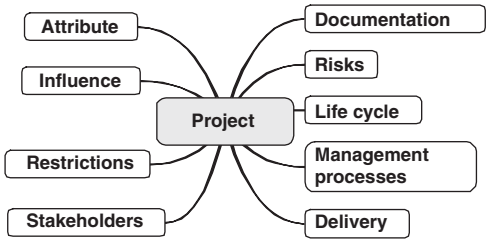

Figure 4 Trivial categorization.

At the next stage we compose more precise concepts and hierarchies by analysing the glossary and previously built elements. First, we employed the top-down design strategy to create meta-concepts such as 'Influence', 'Life cycle', 'Management processes' etc., then using the bottom-up strategy, we tried to fit the terms and concepts into the meta-concept. Moreover, we created the relationships between the concepts. The output of this stage is a large and detailed map, which covers the project management domain in a hierarchical way. Because of the huge size of this map it is difficult to include it in the paper; for this reason only the three-level mind map is presented in Figure 5.

The main goal of this stage is the creation of a set of preliminary concepts and the categorization of those terms from the glossary into meta-concepts. In other words, we combined concepts into more general and abstract notions and created the structure by summarizing or synthesis. In that way we have composed more precise concepts and hierarchies by analysing the glossary and previously built visual structure.

Why do we need to do two opposite actions with the same series? These actions – synthesis and analysis – are essential for the development of a new concept at first and allow to form a general idea on the basis of elementary concepts. It helps to check if everything is neatly set up in the structure.

At the final stage of this step, the initial visual structure of the glossary terms is examined. Working with concepts, we combined the concepts and terms in the meta-concepts and have established a relationship between them. As a result the ontology was only enriched with the new concepts according to relations among them, so the ontology was developed as a flat structure. Understanding the specific of the domain area and the relationship among the constructed concepts, the expert in the project management can revise the created hierarchical structure to conjunct some meta-concepts according to the domain area-specific knowledge.

For example, knowing that the life cycle of the project consists of the determined phases and each of these phases and the whole project have the same management processes, we can put the concept 'Management processes' under the concept 'Life cycle' into the hierarchical structure. As well, the 'Methodology' concept can include the 'Life cycle' and 'Documentation' sub-concepts. So the

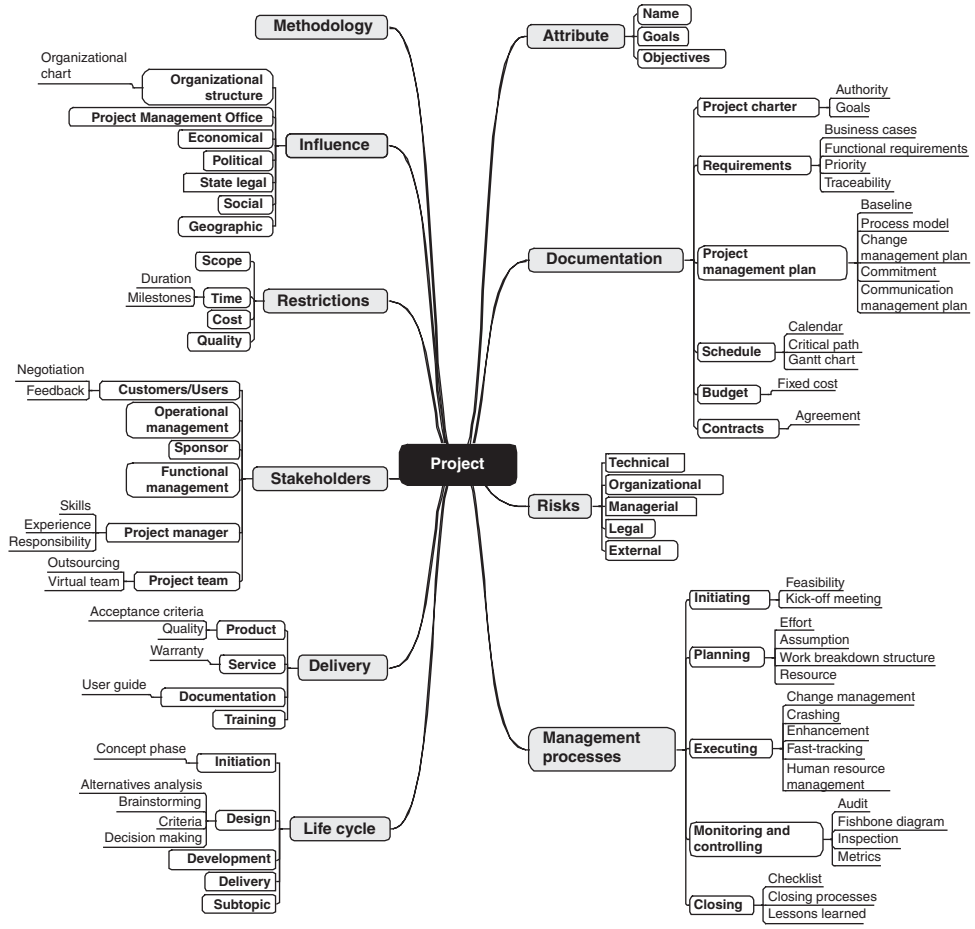

Figure 5 Details of first-level categorization.

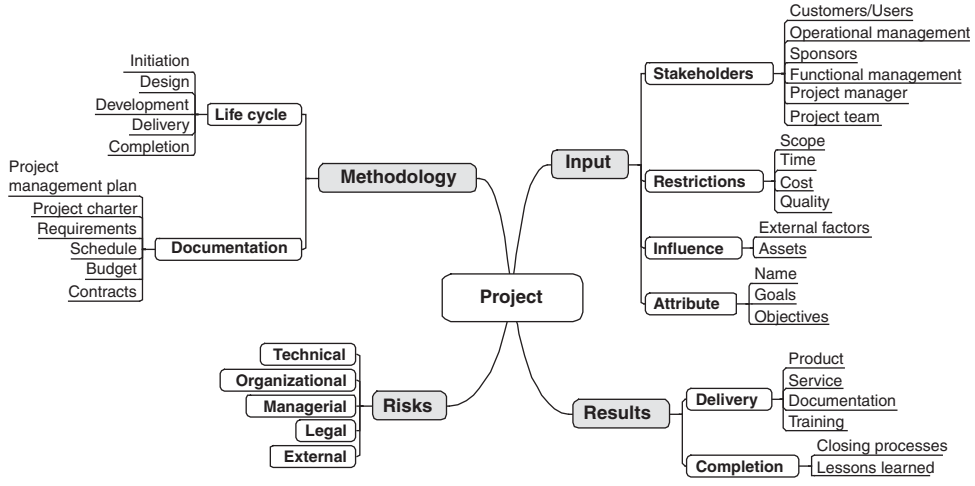

Figure 6 General ontology.

knowledge of the domain area allows us to revise not only the hierarchical relations between meta-concept and their concepts but also join some meta-concepts into new ones using the domain expert knowledge. Therefore, based on the detailed map, we built the new general ontology shown in Figure 6. The visual structures presented at this step 'Laddering' illustrate the idea of how an ontology can bridge the gap between the chaos of unstructured data presented in the glossary and be a clear means of showing mapped representations.

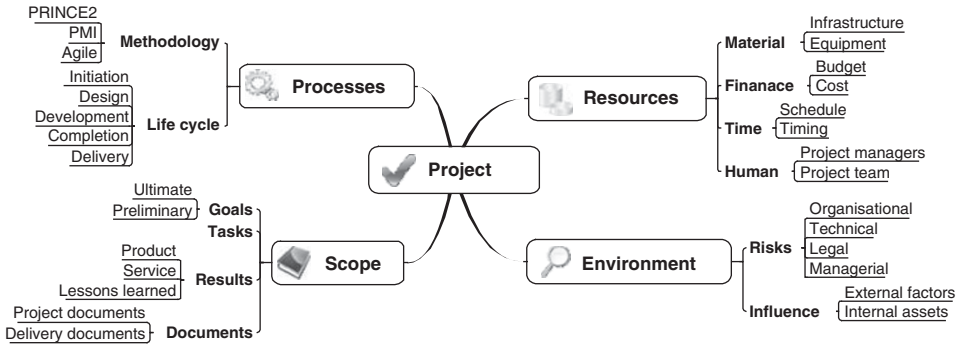

Figure 7 Harmony and clarity in the ontology.

Step D: refinement and orchestration

As described in the algorithm, the final step is devoted to making the ontology beautiful from ontology engineering point of view. We used practical tips and hints mentioned above that can harmonize the designing of an ontology.

In addition, we re-built the general ontology while taking into consideration the harmony and clarity factors. Comparing Figures 6 and 7 one can see these changes. Consequently, we tried to balance the depth of the branches. Another feature of harmony is having the same relationship at each level. Since this is not easy to achieve, we tried to differentiate the level of the nodes based on the relationships in the same depth. For example, all nodes with the 'has' relationship are at the same level and all the node with the 'has part' relationship are also at the same level. Moreover, to achieve clarity we removed all unnecessary nodes and use the standard relationships that are easy to understand.

And after using the above-mentioned recipe the ultimate ontology was developed (see Figure 7).

We understand that other specialists in another company may design the totally different ontology. This fact proves again the subjective nature of ontology design especially on the upper levels of domain ontologies. Although the leaves of the tree may be very resembling the branches could vary both in number and name. It may be explained by the different style and manner of the categorization procedure used by the analysts.

Categorization deals with the creating of classes of objects that share common features. If two analysts see different features they will compose different categorization trees. They both may be correct. However, there is no visible way to assess the quality of those ontologies besides finding of a super-expert who may become the judge.

Future research directions

All the visual models of knowledge are node-link representations in which ideas are located in nodes and connected to other related ideas through a series of labelled links. The research on knowledge mapping in the last decade has produced a number of consistent and interesting findings (O'Donnell *et al*, 2002; Dicheva & Dichev, 2008). People recall more central ideas when they learn from mind map or ontology than when they learn from text and those with low verbal ability or low prior knowledge often benefit the most. The use of ontology engineering also appears to amplify the benefits associated with structured approach. Fruitful areas for future research on ontology mapping include examining whether visual representations reduce cognitive load, how map learning is influenced by the structure of the information to be learned, and the possibilities for transfer.

The future research will be devoted to the theoretical and methodological issues of categorizing and laddering processes. It seems to be challenging to study the feasibility of using the suggested approach in the new forms of company learning, for example, blended education. The great interest in visual approach is seen in many new graphical business models. These models are roadmaps or strategic plans (Alitek Consulting, 2003), knowledge maps (O'Donnell *et al*, 2002) that show where knowledge is stored in companies, topic maps aimed at the representation and interchange of knowledge, with an emphasis on the *findability* of information (Dicheva & Dichev, 2005) and many others.

Cognitive aesthetics in ontology design covers a range of aspects from visual presentation and the elegance of the underlying structure to less tangible aspects such as user comprehension and satisfaction; a good ontology will provide a rich user understanding and afford intellectual stimulation. We are seeing the emergence of cognitive ergonomics as a growing research area and the development of increasingly sophisticated tools such as special metrics and indicators of user perception engagement, yet much work remains to be done to maximize the true teaching potential that is now available to ontology designers.

Our next projects are devoted to the study of deeper cognitive basics of structuring processes and are aimed at developing of technologies and tools that scaffolds the visual design and representing of the learning ontologies.

Conclusion

The described approach and the numerous study of many researchers (Eisenstadt *et al*, 1990; Davies *et al*, 2002;

Gómez-Pérez *et al*, 2004) allow us to sketch some patterns of use what to enhance the effectiveness of visual ontological models. Ontology mapping appears to be particularly beneficial when it is used in an ongoing way to consolidate or crystallize corporate experiences. In this mode, visual mapping in a reflective way help to enhance knowledge acquisition from the communication.

Now we can see how many new visual models (roadmaps, knowledge maps, topic maps, etc.) have become popular in business applications. Some of them have also an ontological base. It seems that in the future visual ontological design will be a must in enterprise modelling.

Our research stresses the role of ontology orchestrating for developing ontologies quickly, efficiently and effectively. We follow David Johnassen's idea of 'using concept maps as a mind tool'. The use of visual paradigm to represent and support the knowledge codification process not only helps professionals to concentrate on the problem rather than on details, but also enables specialists to process and understand great volumes of information.

The development of beautiful knowledge structures in the form of ontologies provide learning supports and scaffolds that may improve the understanding of substantive knowledge. As such, they can play a part in the overall pattern of KM by facilitating for example analysis, comparison, generalization, and transferability of understanding to analogous problems.

Constructing a single ontology may be used for different purposes depending on the application. Here it needs to mention that the majority of business ontologies will play several roles depending on their usage. The same ontology can be used for training purposes, for knowledge sharing in a particular area, for decision-making process support, for project process development clarification. A well-chosen analogy or diagram can make all the difference when trying to communicate a difficult idea to someone, especially a non-expert in the field. Ontology can survey the entire area as a whole, which facilitates understanding and helps to take into account various factors when solving problems.

Ontologies also can be used to visualize and analyse the employee's knowledge and understanding. Through visual inspection the manager can assess the employee and it is possible to detect gaps and misunderstandings in his/her cognitive model of the learnt knowledge. But all specialists are individuals, and they may disagree among themselves.

Acknowledgements

This work was partially supported by grants of Russian Foundation for Basic Research.

References

ALITEK CONSULTING (2003) What is strategic mapping? [WWW document] http://www.alitek.com.au/strategic-mapping.htm (accessed 1 August 2003).

BLANCHARD E, MIZOGUCHI R and LAJOIE S (2009) Addressing the interplay of culture and affect in HCI: an ontological approach. In *Proceedings of HCI International 2009*, Part III. (JACKO JA, Ed) LNCS 5612, pp 575–584, Springer, U.S.A.

BLAZQUEZ M, FERNANDEZ M, GARCIA-PINAR JM and GOMEZ-PEREZ A (1998) Building ontologies at the knowledge level using the ontology design environment [WWW document] http://oa.upm.es/6457/1/Building_Ontologies_at_the_K.pdf (accessed 19 September 2012).

BOOSE JH (1990) Knowledge acquisition tools, methods and mediating representations. In *Knowledge Acquisition for Knowledge-Based Systems* (MOTODA H, MIZOGUCHI R, BOOSE J and GAINES B, Eds), pp 123–168, Ohinsha Ltd, Tokyo.

BRUSILOVSKY P, YUDELSON M and GAVRILOVA T (2005) Towards user modeling meta ontology. In *Proceedings of 10th International conference User Modeling* (ARDISSONO L, BRNA P, MITROVIC A, Eds), LNAI 3538, pp 448–452, Springer, New York.

BUZAN T (2005) *Mind Map Handbook*. Thorsons, London.

CONLON T (2006) Formative assessment of classroom concept maps: the reasonable fallible analyser. *Journal of Interactive Learning Research* **17(1)**, 15–36.

CUNHA M and PUTNIK G (2006) 'On the dynamics of Agile/Virtual enterprise reconfiguration. *International Journal of Networking and Virtual Organisations (IJNVO)* **3(1)**, 102–123.

DAVIES J, VAN HARMELEN F and FENSEL D (Eds) (2002) *Towards the Semantic Web: Ontology-Driven Knowledge Management*. John Wiley & Sons, Inc., New York.

DICHEVA D and AROYO L (2004) Concepts and ontologies in web-based educational systems. *International Journal of Continuing Engineering Education and Life-long Learning* **14(3)**, 187–190.

DICHEVA D and DICHEV C (2005) Authoring educational topic maps: can we make it easier? In *Proceeding of 5th IEEE International Conference on Advanced Learning Technologies*, ICALT 2005, July 5–8, Kaohsiung, Taiwan, pp 216–219.

DICHEVA D and DICHEV C (2008) Ontological support for learning content management. *Scientia Journal,* Special Issue of Semantic Web for Educational Systems, **19(2)**, 68–76.

EISENSTADT M, DOMINGUE J, RAJAN T and MOTTA E (1990) Visual knowledge engineering. *IEEE Transactions on Software Engineering* **16(10)**, 1164–1177.

EPPLER M and PLATTS K (2009) Visual strategizing: the systematic use of visualization in the strategic planning process, long range planning lrp. *International Journal of Strategic Management* **42(1)**, 42–74.

FENSEL D (2001) *Ontologies: A Silver Bullet for Knowledge Management and Electronic Commerce*. Springer, New York.

FIRESTONE J and MCELROY M (2005) Doing knowledge management. *The Learning Organization* **12(2)**, 189–212.

GAVRILOVA T (2010) Orchestrating ontologies for courseware design //. In *Affective, Interactive and Cognitive Methods for E-Learning Design: Creating an Optimal Education Experience* (TZANAVARI A and TSAPATSOULIS N, Eds), pp 155–172, IGI Global, U.S.A.

GAVRILOVA T and BOLOTNIKOVA E (2012) Development of dermatovenereology ontology. In *Proceedings of Distributed Intelligent Systems and Technologies Workshop,* (SHKODYREV V, Eds.), pp 69–72, St. Petersburg, SPbGTU, Russia.

GAVRILOVA T, BRUSILOVSKY P, YUDELSON M and PUURONEN S (2006) Creating ontology for user modelling research. In *Workshop Ubiquitus User Modeling on European Conference on Artificial Intelligence ECAI 2006,* (BREWKA G, CORADESCHI S, PERINI A and TRAVERSO P, Eds), pp 11–15, IOS Press, Riva del Garda, Italy.

GAVRILOVA T, DICHEVA D, SOSNOVSKY S and BRUSILOVSKY P (2005a) Ontological web portal for educational ontologies. In *Proceedings of Applications of Semantic Web Technologies for E-Learning Workshop (SW-EL'05) in conjunction with 12th International Conference on Artificial Intelligence in Education (AI-ED'05),* (AROYO L and DICHEVA D, Eds), pp 19–29, Amsterdam.

GAVRILOVA T, FARZAN R and BRUSILOVSKY P (2005b) One practical algorithm of creating teaching ontologies. In *Proceedings of 12th International Network-Based Education Conference NBE 2005*, pp 29–37, Rovaniemi, Finland.

GAVRILOVA T, KUROCHKIN M and VEREMIEV V (2004) Teaching strategies and ontologies for e-learning. *International Journal of Information Theories and Applications* **11**(**1**), 35–42.
GAVRILOVA T and LAIRD D (2005) Practical design of business enterprise ontologie. In *Industrial Applications of Semantic Web* (BRAMER M and TERZYAN V, Eds), pp 61–81, Springer, New York.
GAVRILOVA T and VOINOV A (1998) Work in progress: visual specification of knowledge bases LNAI. In *Tasks and Methods in Applied Artificial Intelligence* (DEL POBIL AP, MIRA J and ALI M, Eds), pp 717–726, Springer, Berlin Heidelberg.
GRUBER T (1993) A translation approach to portable ontology specifications. *Knowledge Acquisition* **5**(**2**), 199–220.
GUARINO N and GIARETTA P (1995) Ontologies and knowledge bases: towards a terminological clarification. In *Towards Very Large Knowledge Bases: Knowledge Building & Knowledge Sharing* (MARS N, Ed), IOS Press, Amsterdam, pp 25–32.
GÓMEZ-PÉREZ A, FERNÁNDEZ-LÓPEZ M and CORCHO O (2004) *Ontological Engineering with Examples from the Areas of Knowledge Management, e-Commerce and the Semantic Web*. Springer-Verlag, London.
JONASSEN DH (1998) Designing constructivist learning environments. In *Instructional design models and strategies* (REIGELUTH CM, Ed) 2nd edn, Lawrence Erlbaum, Mahwah, NJ.
KINCHIN IM, DE-LEIJ F and HAY DB (2005) The evolution of a collaborative concept mapping activity for undergraduate microbiology. *Journal of Further and Higher Education* **29**(**1**), 1–14.
KNIGHT C, GAŠEVIĆ D and RICHARDS G (2006) An ontology-based framework for bridging learning design and learning content. *Educational Technology & Society* **9**(**1**), 23–33.
LEYDESDORFF L (2006) *The Knowledge-Based Economy Modeled, Measured, Simulated*. Universal-Publishers, Boca Raton, Florida, USA.
MARTIN G (2007) Beauty is in the eye of the beholder. *The Phrase Finder*. [WWW document] http://www.phrases.org.uk/meanings/59100.html (accessed 4 December 2007).
MERRIAM-WEBSTER ONLINE DICTIONARY (2008) Orchestration [WWW document] http://www.merriam-webster.com/dictionary/orchestration (accessed 9 November 2008).
MILLER G (1956) The magical number seven, plus or minus two: some limits on our capacity for processing information. *The Psychological Review* **63**: 81–97.
MIZOGUCHI R and BOURDEAU J (2000) Using ontological engineering to overcome common AI-ED problems. *International Journal of Artificial Intelligence in Education* **11**(**2**), 107–121.
NECHES R *et al* (1991) Enabling technology for knowledge sharing. *AI Magazine* **12**(**3**), 36–56.
NOVAK J and CAÑAS A (2006) The theory underlying concept maps and how to construct and use them. Technical Report IHMC CmapTools 2006-01, Florida Institute for Human and Machine Cognition, 2006 [WWW document] http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMaps.pdf (accessed 19 December 2013).
NOY N and MCGUINNESS D (2001) Ontology development 101: a guide to creating your first ontology. Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880, March 2001.
O'DONNELL A, DANSEREAU D and HALL R (2002) Knowledge maps as scaffolds for cognitive processing. *Educational Psychology Review* **14**(**1**), 71–86.
PMBOK Guide (2008) *A Guide to the Project Management Body of Knowledge*. Project Management Institute, USA.
SCHREIBER G (2000) *Knowledge Engineering and Management: The CommonKADS Methodology*. MIT Press, Cambridge, MA.
SEBASTIAN A, NOY N, TUDORACHE T and MUSEN M (2008) A generic ontology for collaborative ontology-development workflows. In *Knowledge Engineering: Practice and Patterns*. LNCS 5268, pp 318–328, Springer.
SOWA JF (1984) *Conceptual Structures: Information Processing in Mind and Machine*. Addison-Wesley, Reading, MA.
TU S, ERIKSSON H, GENNARI J, SHAHAR Y and MUSEN M (1995) Ontology-Based configuration of problem-solving methods and generation of knowledge-acquisition tools: application of PROTEGE-II to protocol-based decision support. *Artificial Intelligence in Medicine* **7**: 257–289.
USCHOLD M (1998) Knowledge level modelling: concepts and terminology. *The Knowledge Engineering Review* **13**(**1**), 5–29.
USCHOLD M and GRUNINGER M (1996) Ontologies: principles methods and applications. *Knowledge Engineering Review* **1**(**1**), 96–137.
VESTAL W (2005) *Knowledge Mapping: The Essentials for Success*. APQC Publication, Texas, USA.
WERTHEIMER M (1945) *Productive Thinking*. Harper Collins, New York.
WIELINGA B, SCHREIBER A and BREUKER J (1992) KADS: a modelling approach to knowledge engineering. *Knowledge Acquisition* **4**(**1**), 23–39.

About the authors

Tatiana Gavrilova is a Head of Information Technologies in Management Department at Graduate School of Management in St. Petersburg University. She has more than 100 publications (43 in English) in the field of knowledge engineering and knowledge management. She has lecturing and consulting experience at Finland, France, Italy, Poland and Estonia. In 1998 and 2004, she has been Fulbright Senior Research Scholar and Lecturer in Penn State University and University of Pittsburgh (USA).

Irina Leshcheva works as a Senior Lecturer in Graduate School of Management of Saint-Petersburg University. Her main research interests are related to using of conceptual models in teaching focused on student knowledge assessment. Also she works in the field of creating and merging ontologies for knowledge management taking into consideration the influence of cognitive styles.

Elvira Strakhovich is a Senior Lecturer in Graduate School of Management of Saint-Petersburg University. Her research interests are focused on the project management and ontology usage in education.